Performance Testing

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Introduction

Interest and Benefit

Background

Key Parameters

Summary
Operation of Thermal Power Plants

- Fuel Consumption
- Grid Capacity and Regulation
- Operation
  - Staff: qualification and qty
  - Maintenance
- Electrical (and Thermal) Output ↔ Market price
Performance Testing - Introduction

Involved Parties
### Performance Testing – Introduction

#### Terms in Use

<table>
<thead>
<tr>
<th>Performance Test</th>
<th>Guarantee Test</th>
<th>Acceptance Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment of Technical Condition of the Plant, e.g. at the end of an O&amp;M Contract</td>
<td>Assessment of contractually fixed guarantees</td>
<td>Assessment of contractually and/or administratively fixed guarantees</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field Test</th>
<th>Shop Test</th>
<th>Reliability Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment of the plant’s as built field performance</td>
<td>Assessment of the plant’s performance in the workshop</td>
<td>Assessment of the plant’s behaviour / consumables under operational conditions</td>
</tr>
</tbody>
</table>
Performance Testing – Introduction

Hierarchy of applicable references

- Guarantees (contract)
- Test procedure
- Codes and Standards
Performance Testing – Interest and Benefit

<table>
<thead>
<tr>
<th>Introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest and Benefit</td>
</tr>
<tr>
<td>Background</td>
</tr>
<tr>
<td>Key Parameters</td>
</tr>
<tr>
<td>Summary</td>
</tr>
</tbody>
</table>
Involved Parties

- EPC Contractor
- Operator / Owner
- Regulatory Framework
EPC Contractor / Supplier

- Field / On-Site Quality Assurance
- Reliable and trustable assessment of plant characteristics / contractual duties
- Release of Cash Flow
Performance Testing – Interest and Benefit

Involved Parties

- Operator / Owner
- Regulatory Framework
- EPC Contractor
Operator / Owner

- Reliable and trustable assessment of plant characteristics / contractual framework → Benchmark for future, monitoring
- Safety in terms of plant’s economic operability under volatile market conditions
- Release of payments is bound to technical assessment
Performance Testing – Interest and Benefit

Involved Parties

- EPC Contractor
- Regulatory Framework
- Operator / Owner
Regulatory parties

• Approval of plant’s compatibility with grid requests
• Approval for the success of political measures to reduce environmental impacts
• Approval of plant’s characteristics whether to be in compliance with regulatory requirements
Performance Testing - Introduction

Involved Parties – Internal relations

Sub Contractor 1,2,3,…

EPC Contractor

Operator
Internal relations

- **EPC-Contractor**
  - + Approval of sub-contractor's compatibility with guarantees from sub-contract → measure to quantify the sub-contractors portion on over-/ minor performance
  - + Increase of the determination grade to reduce over-all uncertainty for plant approach
  - - Dependency if all involved components are available during test execution

- **Sub-Contractor**
  - + Increased physical background for the component's assessment
  - + Strongly defined overall plant conditions
  - - Dependency if all involved parties are ready for test execution

- **Operator / Owner**
  - + Deeper view inside „black box“
  - + All in one assessment of plant's behaviour (best: without remaining gaps)
Introduction

Interest and Benefit

Background

Key Parameters

Summary
Performance Testing – Background

- Codes and Standards
  - Test procedure
    - Guarantees (contract)
Performance Testing – Background

Codes and Standards

- Performance Test Gas Turbine
  - ASME PTC 22
  - ISO 2314

- Performance Test Steam Turbine
  - ASME PTC 6
  - DIN 1943/IEC 953

- Performance Test Steam Generator
  - ASME PTC4.1, 4.4
  - DIN EN 12952-15

- Performance Test Compressor
  - ASME PTC 10
  - VDI 2045

- Performance Test Condenser
  - ASME PTC 12.2

- Performance Tests Flue gas Cleaning Facility

- Air Emission Measurements
  - VDI …, CEN …, EPA …

- Performance Test for Concentrating Solar Power Plants
  - ASME PTC 52

- Auxiliary Power Consumption Measurements

- Vibration Measurements

- Sound Emission Measurements

- Overall Plant Performance
  - ASME PTC 46

- OTE: Performance Test
  - Test uncertainties
  - ASME PTC 19

- ASME PTC 19

- Performance Test for Codes for Coal, Biomass, Waste to Energy Plants
  - ASME PTC 52

- Temperature Measurements in Combustion ZONES

- Cooling Tower
  - BS 4485
  - DIN 1947
  - ASME PTC 30

- Auxiliary Power Consumption Measurements

- Vibration Measurements

- Sound Emission Measurements
Performance Testing – Background

- Guarantees (contract)
- Test procedure
- Codes and Standards
Performance Testing – Background

Technical contents of Contract / Guarantees

- Power Output at dedicated loads
- Heat Rate (GJ/GWh) ⇒ Indication of power plant efficiency
- Electrical Characteristics, e.g.
  - Auxiliary power,
  - Operation test within voltage and frequency limits,
  - Power factor range prescribed
- Water / Steam Parameters
- Emissions (Air, Sound Pressure)
- Vibrations
- Consumption of Water and Chemicals
- Treatment of water and waste water
Performance Testing – Background

Guarantees (contract)

Test procedure

Codes and Standards
The test procedure / procedures

- must individually be prepared and agreed between the parties
- are based on the codes and standards to be applied
- define the interfaces between the codes to be applied
- strongly refers to the plant’s “as built” conditions
- define how the computations / balances shall be performed
- transparently summarize the way to correct the gained results from “as measured” to “as guaranteed” conditions
- present the uncertainty approach
- ARE the interface between contract / guarantees and applicable codes and standards
- show HOW single tasks shall be done
Performance Testing – Key Parameters

- Introduction
- Interest and Benefit
- Background
- Key Parameters
- Summary
Performance Testing – Key Parameters

Key parameters for successful performance testing

Qualification of staff

- Availability of adequate test equipment
- Project Management
  - “Logistics”
  - Capacities
Performance Testing – Key Parameters

Equipment: Measurement system

- **Accuracy Class of Instruments**
  - RTD (PT100) up to 150 °C < 0.1 K
  - Differential pressure sensors < 1 mbar
  - Gauge and absolute pressure sensors < 0.1 %
  - Powermeter (Yokogawa) < 0.1 %

- **Accredited Calibration / QA**
Performance Testing – Key Parameters

Locations of TÜV SÜD performance test related activities in recent years
Performance Testing – Key Parameters

Project Management – Single resource @ HQ Munich

Head: R. Szamer (Dipl. Ing.)

Senior PT Engineers:
T. Amann       (Dipl. Phys.)
J. Krammer    (Dipl. Ing.)
F. Michl          (Dipl. Ing.)

Calibration Laboratory
DAkkS K-00701 for Pressure and Temperature
BU Electro-, Building Technology (IS-TAF)
Coordination: H. Schaube

Thermodynamic Measurements
Acceptance Tests

J. Radtke (MSc., DI)
C. Räcke (PT Technician)
C. Weigl (Dipl. Ing.)

Staff of TÜV SÜD Legal Entities
Dr. X. Maurus (Freelancer)
Stefan Geisse (DI, Freelancer)

Outdoor Guideline
Maschinery-Guideline
Acoustic and Vibration Measurements

T. Fleckenstein (Bach.)
J. Franke (Dipl. Ing.)
J. Steimer (Dipl. Ing.)

Emission Measurements
BU Environmental Services (IS-US)
Coordination: B. Thull
Regional Staff of TÜV SÜD IS
Performance Testing – Key Parameters

Project Management – TÜV SÜD resources - Perspective for future

Political Map of the World, April 2007

Interaction, Exchange,...
Performance Testing – Key Parameters

Typical tasks – Test preparation

- “Test Design” → Issuing / Review of the PT procedures with respect to
  - Contract figures, reference conditions and compliance to codes and standards.
    Calculations for Flow, Power Output, Heat Rate.
  - Application of corrections and provision of correction curves
  - Review of foreseen test instrumentation
  - Compatibility of instrumentation and computation approach with requests from uncertainty computation
- Preparation of the test equipment, e.g. calibration of the measuring devices to a traceable standard, allocation of test equipment fitting the accuracy and operational requests
- Equipment logistics / Arrangement of Shipment to Site / Requirements for Staff Mobilisation (Permission of TÜV SÜD Management, Visa, Work Permit, Security Concept, Travel Arrangement)
Typical tasks – On site activities

- Interaction between Owner and Contractor.
- Installation resp. supervision of instrument installation
- Check of calibration status
- Check test conditions resp. status of the unit / plant with regard to relevant documents, such as Contract, Codes and Standards.
- Participation, Guidance and Consulting for the execution of the performance test runs at dedicated loads
- Data recording / Take over of data sets
- Issuing / Review of the preliminary test computations
Typical tasks – Evaluation of Performance Tests and Reporting

• Computation of performance test results and comparison to the evaluation reports provided by the involved parties
• Final Test Report including recommendations to client for the correctness and acceptability of the text execution
• Final statement concerning the fulfilment of the performance guarantees
Performance Testing – Summary

- TÜV SÜD is an independent partner for performance testing (PT)
  - Related Activities and Computation results have a high level of acceptance worldwide

- TÜV SÜD’s provides a large scale of temporary test equipment with adequate quality characteristics worldwide in large quantities
  - Measurement records will be available at the requested accuracy level

- TÜV SÜD is a reliable partner for PT with highly experienced staff and a long term experience in PT related activities
  - Necessary steps will be considered duly
Acceptance and performance tests: Ireland
Combined cycle power plant Poolbeg, 487 MW output

ESB Electricity Supply Board Dublin (IRL), Power & Systems

Our solution

- Execution of the acceptance test and performance test.

TÜV SÜD services
- Review test procedure for verification of contractual guarantees and allocation of measuring points
- System engineering ➔ Provide adapted test program and prepare adapted evaluation methodology
- Execution in accordance with applicable ASME standards PTC 22, PTC 4.4, PTC 6, PTC 46
- Provide, calibrate and install test instruments and data acquisition system on site
- Adaption, control and supervise power plant settings
- Read and record test data and fuel sampling during performance tests at different loads.
- Evaluate test results for combined cycle and individual components. Supply final report including recommendable technology investments and operational improvements to owner.

About the project

Project description
- Thermodynamic and Power Output Measurements
- Assessment of efficiency and performance of Gas Turbine, Heat Recovery Steam Generator, Steam Turbine, Combined Cycle Plant
- Comparison with year 2000 guarantee test results
- Guidance for recommended measures

Performance period
- 2000 (guarantee/acceptance tests)
- 2010 (performance tests)

Outcome

- Independent measurement and evaluation of thermal plant performance including sub-components as a baseline
- Determination of performance characteristics at representative operation conditions after 10 years of operation
- Identification of the most important losses from the combined cycle. Proposals to facilitate technical measures to enhance cycle efficiency
Acceptance tests: Oman
Combined cycle power plants Sohar 2 & Barka 3, 1500 MW output

Doosan Engineering & Construction Seoul (ROK), Power & Systems

**Our solution**

Execution of measurements for the acceptance tests of the heat recovery steam generators.

**TÜV SÜD services**

- Review test procedure for verification of contractual guarantees and allocation of measuring points
- System engineering / adaption of data acquisition concept and software to project requirements
- Calibrate, install and rent test instruments and data acquisition system on site
- Prepare custom documents and support customer’s logistic department with material shipment in due time
- Read and record test data during performance tests
- Presentation and hand over of test data to the customer

**About the project**

**Project description**

- Instrumentation and thermodynamic measurements on 4 HRSG’s at Sohar 2 and Barka 3 new built CCPP power plants in the Sultanate of Oman
- Parallel execution of both projects

**Performance period**

- 2013

**Outcome**

- Impartial provision of reliable test data on the performance of the HRSG’s
- Consultancy on the code compliance with regard to temporary instruments at the HRSG system boundary
- Flexible response to changes in the time schedule for the acceptance tests
Guarantee tests: Indonesia
Coal power plant, 660 MW output

PT Cirebon Electric Power (RI), Power & Systems

Our solution
Third party supervision of the verification of guarantee tests. Review and witness services.

TÜV SÜD services
- Review test procedures for compliance with Construction Services Contract and test codes (ASME PTC4, PTC6, PTC46).
- Acting as “Owner’s Engineer” for the clearance of deviations
- Inspect test point locations and additional test equipment. Review quality and trustability of calibration certificates for temporary instrumentation
- Evaluate preliminary test results
- Review calculations and reports provided by the EPC contractor.
- Issuing a test report detailing shortcomings or deficiencies found throughout the tests with recommendation to the owner regarding guarantee fulfillment

About the project

Project description
- Witnessing of Guarantee Tests for new built Cirebon coal power plant (Indonesia)
- Consultancy of Owner / Operator for performance testing related topics ➔ Revision of Test Procedure, Supervision of Performance Tests, Performance Evaluation
- Cirebon coal power plant is designed supercritical promising lower CO2 emissions, higher efficiency and environmentally-friendly power generation.

Performance period
- 2012

Outcome
- Third Party Opinion in terms of guarantee conformity
- Flexible on-site review of impacts and sensitivity of short time changes in plant guarantee performance test procedure
- Control of adequate test execution and evaluation methodology
- Verification of contract guarantees
- Baseline for plant performance and for Power Purchase Agreement
Acceptance and Performance tests: Algeria
Combined cycle power plant, 1227 MW output

The Energy Consulting Group Zurich (CH), Power & Systems

Our solution
Witnessing of the acceptance tests for the single units and the total combined cycle power plant as an independent third party.

TÜV SÜD services
• Review and clearance of test procedure for verification of contractual guarantees
• Inspect test point locations and additional test equipment according to test procedure and applicable ASME standards, e.g. ASME PTC22 (GT) and PTC46 (Plant)
• Participation of electric and thermal isolation
• Conduct reliability test runs
• Supervise official performance tests at different loads and fuels (natural gas, oil)
• Control of test data and calculation to physical values. Evaluate preliminary test results
• Independent calculation of tests
• Review reports provided by EPC contractor. Evaluate performance, emission and noise tests and final reporting regarding guarantee fulfillment

About the project

Project description
• Third Party Witnessing and verification of the thermal acceptance criteria for the new built power station Hadjret en Nouss, located in the west of Algiers. This CPP operates on natural gas as the primary fuel with light distillate oil as the backup.

Performance period
• 2009 (acceptance tests)
• 2010, 2011 (annual performance tests)

Outcome
• Guarantee verification by Independent Third Party with high acceptance among the contracting parties
• Detailed knowledge in thermodynamic plant condition at the time of PAC
• Benchmark of the actual power output and heat rate by annual performance tests
Acceptance tests: Kuwait
Combined cycle power plant Az Zour, 560 MW output

CMI Energy, Seraing (B), Power & Systems

Our solution
Execution of measurements for the acceptance tests.

TÜV SÜD services
• Review test procedure for verification of contractual guarantees and allocation of measuring points
• System engineering / adaption of data acquisition concept and software to project requirements
• Calibrate, install and rent test instruments and data acquisition system on site

• Read and record test data during performance tests
• Presentation and hand over of test data to the customer

Outcome
• Impartial provision of reliable test data on the performance of the HRSG’s
• Flexible response to changes in the time schedule for the acceptance tests
• Rapid compensation of measuring equipment failures caused by extreme weather conditions

About the project
Project description
• Challenges included a high number of measurement locations where calibrated high-precision measurement instruments had to be placed within a certain time schedule.

Performance period
• 2010
Acceptance tests: Wales, United Kingdom
Combined cycle power plant Severn Power, 834 MW output

Siemens Plc, Frimley, Camberley (UK) & CMI Energy, Seraing (B) & Siemens AG, Energy Sector, Erlangen (D), Power & Systems

Our solution
Execution of measurements for the acceptance test according to ASME PTC 46 and performance measurements.

TÜV SÜD services
- Review test procedure for verification of contractual guarantees and allocation of measuring points
- System engineering / adaption of data acquisition concept and software to project requirements
- Rental of test instrumentation and of gas fuel sample cylinders
- Calibrate, install and system check of the test instruments and the data acquisition system on site. Fuel sampling and arrangement of analysis
- Read and record test data during performance tests
- Presentation and hand over of test data to the customers.

Outcome
- Guarantee verification by Independent Third Party with high acceptance among the contracting parties
- Installation of a high number of temporary measuring instruments within given deadlines
- Synergy effects by parallel measurements of HRSG and total plant performance
- Benchmark of the actual power output and heat rate by performance test 2012

About the project
Project description
- The central challenges included a high number of measurement locations where calibrated high-precision measurement instruments had to be placed within certain deadlines.

Performance period
- 2009 (acceptance tests)
- 2012 (performance tests)